Workplace Health,
Safety and Compensation
Commission
of New Brunswick

WHSCC
CSSIAT

Commission de la santé, de la
sécurité et de l'indemnisation
des accidents au travail
du Nouveau-Brunswick

Accident Investigation Report on the *Explosion and Fire at the Irving Oil Refinery Saint John, New Brunswick*

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Introduction

At approximately 9:30 am on Tuesday, 9 June 1998, an explosion and fire occurred at the Irving Oil Refinery in Saint John. One worker, William Hackett, who was in the immediate vicinity, was killed as a result of this catastrophic event. Another worker was taken to hospital with minor injuries.

When the explosion occurred, affected operations were immediately shut down and the proper authorities contacted. The local Emergency Measures Organisation organised emergency response agencies, including municipal fire and police departments. The fire department assumed the role as lead agency in order to contain the immediate hazard. Within minutes, the fire was contained and after several hours, the site was considered safe for initial inspection.

Several other agencies were immediately notified of the incident and their representatives arrived on site during or shortly after the event occurred. These agencies included the:

- Workplace Health, Safety and Compensation Commission (WHSCC)
- Fire Marshall's Office
- Department of Labour, Safety Code Services
- Department of the Environment
- Coroner's Office

Once the Fire Department eliminated the fire hazard and the Police Department concluded that the situation did not constitute a criminal matter, WHSCC launched its investigation into the cause of this fatal workplace accident. This was in accordance with its obligations under Section 28 of the *Occupational Health & Safety Act (OHS Act).* WHSCC assumed the lead in the investigation, with the mutual agreement of the other agencies involved.

This report provides a summary of the events surrounding the incident, the Commission's investigation, its findings, conclusions and recommendations. This report is a compilation of work done by the Commission's officers; material gathered during the investigation; and the information provided by various engineering and metallurgical consultants in their reports. This report is an edited version of the Commission's internal accident investigation report. References to names of witnesses and their statements, as well as specific information relating to the company's business process have been removed in accordance with the confidentiality protection afforded under Section 40 of the *OHS Act.*

Description of the Equipment

The explosion and fire occurred in the east cell of furnace F12501, part of the hydrocracker unit located in an area of the refinery known as the South Satellite.

The Hydrocracker Unit

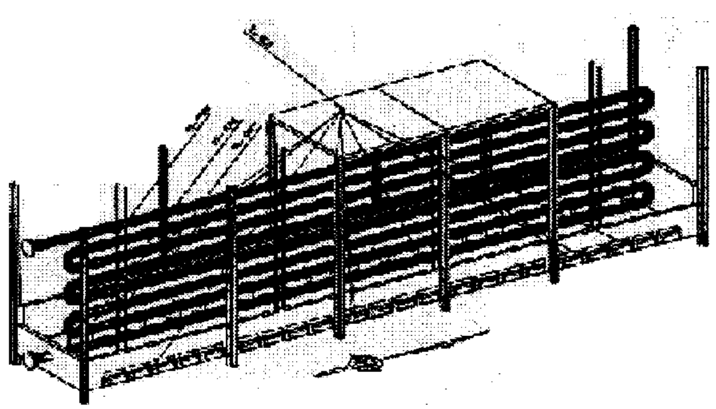
The hydrocracker unit consists of a heater and two reactor units. The hydrocracker unit uses both mechanical and chemical processes to produce high-octane gasoline from secondary crude products. Mechanically, feed stock from the crude unit is heated in combined feed exchangers and then pumped through the hydrocracker fired heater to the hydrotreater reactor, then to the hydrocracker reactor. Chemically, contaminant elements are removed from the feed stream in the hydrotreater reactor and the hydrocarbon molecules are then broken or "cracked" and combined with hydrogen, in the hydrocracker reactor, at high temperatures and pressures in the presence of a catalyst. Product from the hydrocracker reactor is then cooled in the combined feed exchanger, before being sent to storage.

The Hydrocracker Heater

The hydrocracker heater was a conventional "cabin" style refinery furnace. It consisted of two individual ground level cells that constitute the "radiant" section. A central "convection" section surmounted the two cells. A tall self-supporting steel stack rose from the convection section.

Each radiation cell (east & west) was fabricated from steel plate on all six sides and lined with monolithic refractory insulation. An exterior framework of structural steel, resting on concrete foundation piers approximately one foot off the ground supports the box-like structures.

Each radiation cell had a single centrally located longitudinal bank of tubes stacked 8 high. These tubes are 8" in diameter, manufactured from 347 stainless steel with a minimum design wall thickness of 0.59 inches and overall length of 55' 6". By convention, the tubes are numbered one through eight from bottom to top. The tubes are held in place by pipe supports located at four different locations along the length of the bank.

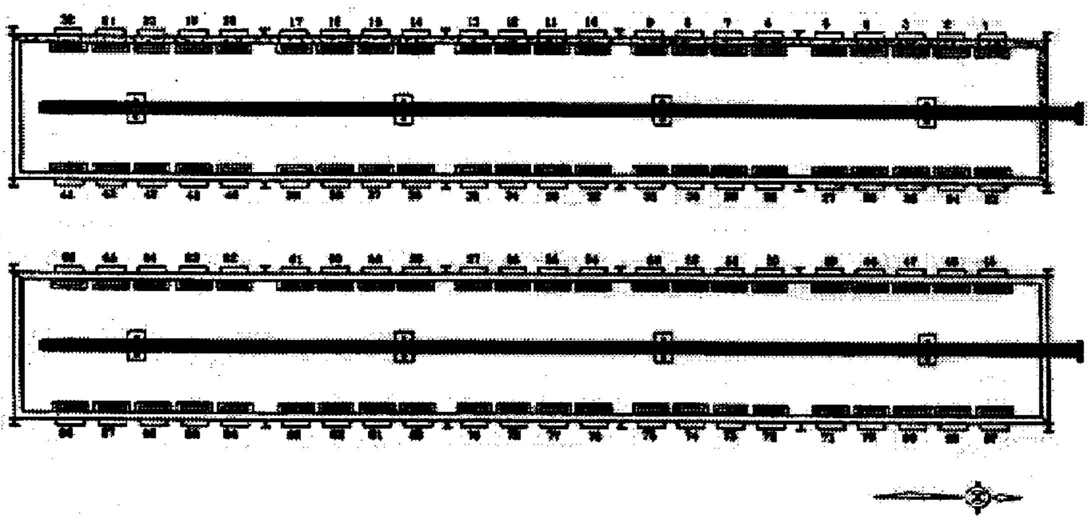


Scaled isometric view of the east cell interior, showing the tube bank and temperature sensors

The Process

The heater was designed to process a high-volume continuous flow of crude oil, at high pressure. The flow was split and went through individual passes in the east and west cells of the fired heater. After being heated, the product from the two cells combined again downstream from the heater before entering the hydrotreater reactor.

Heat for the heater cells was supplied by a series of 22 gas burners on each side of each cell, a total of 88 burners. The burners were located along the bottom of the heater sidewalls. An observation port was fitted immediately above each burner. A sliding 3-hole air damper was located on the bottom of each burner box.



Top-down scaled plan view of radiant sections showing burner numbering system

The burners were set in refractory box-like recesses that were only open to the top. This box-like recess directed the burner flame upward so that the flame would not make direct contact with the tube surface. Heat from the burners was transferred through the tube walls to the process fluid. Skin temperatures of the operating tubes were typically in the order of 950 - 1000 degrees Fahrenheit.

The burners were fuelled with refinery fuel gas that consisted generally of methane, ethane, propane, butane and hydrogen in various mixtures. Fuel gas for the burners went through a control valve and then into a four-inch pipe header that surrounded each cell. Fuel gas from the header was conveyed to each individual burner by ¾-inch pipelines coming off the top of the header, then downward and into the burners. A ball valve was located in the vertical run of the ¾-inch supply line for control of fuel supply to each individual burner.

Furnace Instrumentation

The hydrocracker was designed to run more or less automatically, but could be overridden by operator commands from the main control room. Sensing instrumentation within the unit were tied into a centralised distributed control system where operators tracked numerous parameters.

Furnace feed temperature was monitored using thermocoupler sensor temperature indicators. These indicators measured furnace inlet temperatures as well as outlet temperatures in both the east and west cells.

The stack contained a temperature indicator at its base to measure the temperature of the gases leaving the furnace through the stack. In addition, an oxygen sensor in the stack gave the percent of excess oxygen in the flue gases being discharged from the furnace.

Each cell contained three thermocoupler sensors located on tubes 1, 5 and 8. These were welded to the bottom of the tube, about four feet from the northerly end of the tube bank. They were used to measure tube skin temperatures. In addition, each cell contained a temperature indicator set in the approximate centre of the inside cell roof. These were used to measure the arch temperature in the cell.

Pressure gas sensors provided fuel gas header pressure and furnace discharge pressure readings.

Description of the Accident

At approximately 8:50 a.m. on the morning of Tuesday, 9 June 1998, an operator from the north process area called the central control room to report the presence of a smoke plume emanating from the hydrotreater reactor feed furnace stack. At about the same time, the hydrocracker panel operator noted that the hydrocracker furnace stack excess oxygen value was dropping and dispatched a field operator to increase the air to the furnace. Such adjustments must be made manually and cannot be made from the control panel.

William Hackett, an experienced operator, responded to the request and apparently sensed a problem. Mr. Hackett was part of a team of 10 workers responsible for operating and maintaining the unit He made a radio call to his team leader for assistance. The team leader arrived and reviewed the situation with Mr. Hackett. Visual examination indicated apparent normal conditions in the west cell, but the presence of swirling yellow flame was detected in the east cell.

The area technical specialist, responsible for the hydrocracker unit coincidentally had been in the area at the same time and noted the apparent oxygen deficiency inside the furnace. He had observed Mr. Hackett addressing the problem and was satisfied that he was able to handle the situation.

Mr. Hackett was attempting to correct the yellow flame problem by adjusting the burners, but apparently there was no change in the flame pattern. The team leader then went to the nearby south satellite control room to seek the assistance of the engineer. These men, plus the other members of the crew were just leaving the control room to respond to the problem when a violent explosion occurred in the east cell of the hydrotreater reactor feed furnace. A huge pressurised fireball accompanied the explosion. The team leader immediately returned to the control room and initiated emergency shutdown and fire fighting procedures.

Mr. Hackett was killed as a result of this explosion and fire. Rescue teams were unable to reach the deceased for about 2 hours due to intense heat and danger in the area.

Description of the Damage

Flames enveloped the hydrocracker furnace when the explosion occurred. The effects of the fire extended to the heater stack and to the tall steel support structure for the reactor located immediately to the east of the furnace. There was abundant damage to the east cell, little damage to the west cell and a pronounced heat-induced westerly lean to the stack.

An examination of the inside of the east cell revealed that the second tube from the bottom (Tube #2) had struck the east wall with excessive force. At the point of contact, the east wall showed substantial outward displacement and bulging. The east side of the floor had been pushed downward and had sheared away from the base of the east wall. The concrete support pier for the steel column was shattered. There was considerable ground displacement under the unit. Piping and other fixtures surrounding the unit received extensive damage.

Tube #2 was found to contain a longitudinal split approximately 4' 8" long, located about 18 feet in from the south end. The failed portion of the tube had been moved from its central location to the east side of the cell and the other tubes in the bank had collapsed to the floor at the south end of the cell. The top tube remained supported by the flange on the north end. Much of the refractory had been displaced from the roof and east wall and was lying on the floor along with a myriad of broken pieces of pipe supports.

The damage to the west cell was not comparable, as there was no bulging or shearing of the walls. However exterior equipment surrounding this cell had extensive equipment fire damage. In the west cell, the tube bank was still in its original position, standing upright in their pipe supports. The refractory and burners were relatively undamaged. The west cell provided a pre-damaged depiction of the east cell. Extensive exterior fire damage occurred to pipes and surrounding fixtures of the west cell.

The convection section remained intact and did not appear damaged with the exception of exterior heat and fire damage. The stack had a pronounced lean to the west after the fire. The two cylindrical reactor units received extensive fire and heat damage to the exterior surfaces and superstructure as a result of the explosion and fire.

The damage to the heater was extensive and placed the unit out of service. It has since been demolished and replaced by a new unit.

The Commission's Investigation

The Investigators

The Commission was notified immediately of the explosion and fire at the Irving Oil Refinery. A Health & Safety Officer was at the site within minutes. The manager responsible for health & safety inspections in that region joined the officer within the hour. These officers assumed the lead role in the accident investigation.

The Commission hired an independent forensic engineer, A.D. Tupper & Associates, (ADTAL) experienced in refinery investigations, to assist with the investigation. ADTAL was supported by In*nova*corp of Dartmouth, for engineering expertise and Front Line Safety Limited of Dartmouth for their expertise in training systems. The Commission contracted with CANSPEC, an independent metallurgical laboratory in Edmonton, to conduct material tests and analysis work.

Note: Reference in this report to "the Commission's officers" means the Health & Safety Officers of the Commission involved in the accident. The use of the term "Commission's investigators" refers to Health & Safety Officers plus the Commission's consultants involved in the investigation.

Commission investigators, in conjunction with representatives from the Saint John City Police, Saint John Fire Department, the Office of the Fire Marshal and the Department of Labour (Safety Code Services) gathered information and evidence to determine the cause of the explosion. All these agencies have specific mandates and expertise and their responsibilities were carried out in a co-ordinated effort. Initially, twice-daily meetings were held between the various agencies involved to keep everyone up to date and determine further course of action.

Irving Oil Limited had its own representatives and engineering specialists on hand and co-operated with the investigation. Many of the activities, including securing the site, the demolition of the furnace and removal of the material were accomplished with the assistance of the company.

Overview of the Investigation

Initially, the investigators viewed the accident site from a distance, as it was too hot to safely access. Later, the site was secured, access controlled and the Commission's investigators were able to enter the unit to conduct a thorough examination and start their investigation. Unstable equipment and materials from the surrounding area were removed in order to ensure the safety of investigators while not jeopardising the investigation.

Initially, there were few leads as to the cause of the event. As a result, the Commission's investigators had to examine a wide number of possibilities. The Saint John Police took video statements from witnesses and other personnel present on site at the time of the accident. The Commission's officers were able to observe this process and able to have additional questions asked by the police. In addition, Commission investigators interviewed a wide variety of refinery personnel on a broad range of topics, including operations, training and maintenance. Numerous leads and tips, many anonymous, were pursued.

The Commission's investigators took photographs of the scene, the inside and outside of the unit during various stages of its dismantling as well as various components and pieces from the furnace, such as the tube banks and burners. Photographs were taken before, during and after significant events all throughout the investigation. In addition, the Saint John City police provided the Commission with a complete set of photos taken by the police photographer.

Forensic investigators sifted through the rubble and catalogued the debris for subsequent identification and examination. Material was seized and controlled by the Commission as possible evidence. This material was subjected to further examination and analysis. This included tube banks from both cells, burners, pipe and hanger supports from the east cell, as well as fuel and gas samples from the tubes and burners. Fuel and gas samples were analysed at the lab in Dartmouth; and the sample sections from the tubing underwent extensive metallurgical analysis at the lab in Edmonton.

An extensive amount of documentation from the refinery was examined. This included operator turnover logs and team leader shift summary reports for the previous three months, maintenance logs from 1973 on and work orders from 1995 on, equipment specification sheets, temperature trends charts from 1992 on, operator and equipment manuals, operating permits, inspection reports, memos, JHSC minutes, records of crew meetings, notebooks, as well as a variety of other material.

In addition, Commission investigators looked at other material relevant to the operation of refineries, such as: industry standards; industry practices in other jurisdictions; and the application of other legislation, notably the Boiler & Pressure Vessel Act and its Regulations.

Commission staff reviewed reports received from ADTAL, In*nova*corp, Front Line Safety and CANSPEC. All this material was reviewed, discussed and clarified by the Commission's internal Accident Review Committee in order to determine the subsequent course of action.

What was Ruled Out

As the investigation proceeded, there were a number of items that required more in-depth examination. Many of these were ruled out as causes of the accident or contributing factors to the death of William Hackett.

The Saint John Police ruled out sabotage, foul play or any other criminal activity as the cause of the accident.

The Commission's investigators reviewed the response to suppressing the fire resulting from the explosion. Refinery personnel received advanced training in the suppression of hydrocarbon fires. They responded immediately and were aided by the Saint John Fire Department when they arrived at the scene. The response time was not a contributing factor to the fatality.

Specialists from Front Line Safety performed an in-depth review of the operator training program. Following interviews with staff and a review of training documentation, they concluded that the training program was effective and well within industry standards. The accident was not caused by inadequate operator training.

The Commission's investigators reviewed procedures to determine if operators had the necessary authority to deal with emergencies and shut down the furnace. They concluded that the actions taken by refinery personnel just prior to the event were as a result of dealing with an unknown situation as opposed to a lack of authority.

In an earlier scheduled shutdown in 1995, an inspection report indicated a potential metallurgical problem with the tubes in the west cell of the furnace. Commission investigators were able to identify the section of tube referred to in the report. It was extracted and sent to the lab in Edmonton for metallurgical analysis. Subsequent testing concluded the absence of a problem and therefore this tubing was not a contributing factor in the accident.

The furnace also experienced an unexpected spontaneous shut down one week prior to the explosion, which was triggered by an electrical problem. The circumstances surrounding this event were investigated. Refinery personnel performed an investigation at the time of the occurrence and took corrective action. Commission investigators concluded that this event was not a cause, however, the high fluctuating temperatures during start-up may have been a contributing factor.

The Investigation Findings

The Cause

William Hackett was killed on 9 June 1998 as a result of an explosion and fire in the hydrocracker unit at the Irving Oil Refinery. The explosion occurred because the sudden rupture of Tube #2 in the east cell of the unit caused a very combustible combination of process fluid and air to mix. Tube #2 had a stress rupture resulting from extensive local overheating or hot spots, that occurred on at least two separate occasions. Hot spots seriously diminish the life of the tube.

This overheating was caused by long-term flame impingement on the west side of the tube from burner #58. Flame impingement occurs when flame is directed at the tube. It can be caused by refractory debris lodged in or around the burner, redirecting or deflecting the burner flame, coke build up on the burner ports, burner misalignment, or deterioration of all or part of burner tile block.

Metallurgical analysis of the tube showed signs of long term creep crack ruptures on both the interior and exterior of the tube wall, with heat induced build-up of microscopic carbon filaments within the cracks. Metallurgical analysis indicated an initial overheating event or events resulting from temperatures in the order of 1200 - 1300 degrees F for times ranging from 1000 - 18,000 hours. This exposure is believed to have used up 80 - 90% of the total tube life. Just prior to the final failure the same region of the tube was overheated by temperatures reaching 1300 - 1500 degrees F. It is more probable that these two overheating events occurred relatively close together.

An indication of similar conditions, although not as advanced, was found on the same tube, opposite from burner #59. Metallurgical analysis ruled out the presence of a 'pinhole' and shows no evidence of manufacturing or material defects which would have contributed to the failure. ADTAL, In*nova*corp and CANSPEC all reached the same conclusion.

Hot spots had been detected and reported by the operators during the month of May. They made adjustments to the burners to reduce the flame. Towards the end of May, reports of hot spots discontinued and the problem seemed to resolve itself. However, the refinery inspectors/engineering staff did not adequately identify the condition and failed to determine the impact on tube life caused by the presence of hot spots. Therefore the condition worsened. It should be noted that on the morning of the 9th of June, operators were responding to the report of a relatively routine oxygen deficiency problem and not to the earlier reported hot spot situation. As a result, it appears that the operators did not initially perceive themselves to be in danger.

The Signs

There was continuous reporting by operators of visible hot spots on furnace tubes during month of May 1998. Identification of hot spots was based strictly on visual reporting and the logs do not indicate the colour observed by the operators, nor the estimated location. The lack of a high level of descriptive reporting means it is difficult to make a reasonable estimate of the degree of heat, the location or the repeat presence in the same location. Such a description is critical to evaluating tube life expectancy. At the normal skin temperature of 970 degrees F the tube would appear to be the colour black. Hot spots would be detected when the colour changed towards orange/red. This would become apparent at a temperature of approximately 1300 degrees F, well above design specification limits. Tube life, if this temperature is maintained is estimated to be 1000 hours.

The operators followed standard operating procedures by reporting the presence of these hot spots to the shift head operator. Whenever this done, the head operator on shift called in the refinery engineering and inspection staff to evaluate. Refinery engineering and inspection staff examined the situation on a number of occasions. The presence of hot spots was erroneously attributed by engineering and inspection staff to be burning scale. There is no indication that these staff made any quantitative evaluation of the situation with respect to temperature. As a result, they misinterpreted the cause and underestimated the effect of the incandescent areas.

Metallurgical experts indicate scale on Type 347 stainless steel tubes only forms at temperatures in the order of 1300 - 1500 degrees F, well above the design specification limits. They also indicate that tube life at a maintained temperature of 1500 degrees F is estimated to be 8 hours.

The Burners

The shutdown inspection records indicate the regular identification of, and maintenance related to burner repair and debris clean up inside the furnace. There is a history of refinery maintenance orders related to repairing burners. In most cases, but not all, this maintenance was done. There were some situations in the late 1980's where work was identified but not performed at the time of identification. This was not a direct cause of the accident.

The examination of burners during the investigation showed they were operational, but contained debris. Investigators were unable to determine if debris was present prior to the accident as opposed to as a result of the explosion. There is room for improvement in the maintenance of burners, but it is not possible to conclude that the burners received inadequate servicing and maintenance.

Tube Skin Temperature Monitoring

The Refinery Equipment Manual makes references to great improvements in the development of instrumentation for use in refineries. There were three skin thermocouplers located on each tube bank located at locations "experience has shown to operate at higher than average temperature". It is believed that the temperature indicators were installed sometime after the unit became operational. Skin thermocouplers were maintained and two in the east had been replaced in 1995. Skin temperature readings showed normal on the morning of the explosion.

Skin thermocoupler sensors would not detect temperature anomalies any distance from their location. Refinery equipment operating manuals caution that skin point temperature readings may not always be reliable and need to be supplemented by visual inspection. The same documentation describes, in general terms, that change in tube colour is a sign of high tube skin temperature. The logs, although short on descriptive detail, show that visual inspections (3-4/shift) were the main source of high temperature detection and records indicate temperature indicators recorded several over-temperature conditions. The number of visual inspections done per shift appears to be higher than the industry standard.

An optical pyrometer could have been used to determine a more accurate reading of the temperature of hot spots, which would lead to a better evaluation of the impact on tube life. However, there are certain inaccuracies in using the equipment to read temperatures of elongated tubing through a small porthole. Optical pyrometers, instruments for more accurately measuring temperature, were available on site but refinery personnel indicated are that they were not used in this unit because of their inaccuracies.

The end result was that the refinery had no quantitative measure of the skin tube temperatures and relied solely on visual detection. Other refineries use visual inspection first. When a hot spot is detected, the temperature is measured with either an optical pyrometer or an infra-red camera in order to get a more accurate skin temperature reading.

Changes to Tube Skin Temperature Alarms

The tube skin temperature alarms were set at 970 degrees F. The original manufacturer's design specification sheet indicated a maximum operating temperature threshold of 970 degrees F. Refinery operating manuals indicated this temperature threshold to be 1100 degrees F.

As the furnace neared the end of its run and the catalyst in the unit was at the end of its cycle, temperature alarms were triggered more frequently. This particular furnace was scheduled for maintenance shut down in September. Refinery personnel examined the option of adjusting the furnace operating parameters in order to continue production. This involved increasing the alarm set point. The company called the manufacturer and reviewed calculations performed by a professional engineer. Conclusions were that the operating limit was 1139 degrees F. Based on this, engineering authorised an increase in the temperature alarm set point to 990 degrees F.

The Commission's investigation concluded that it was a reasonable, common industry practice to run the furnace harder at the end of catalyst life. Refinery operating procedure manuals describe the parameters for doing so. While this appears to be a common practice, other contacts in the refinery industry advise they would not do so if hot spots had been detected.

Because the tube conditions were not recognised as hot spots, the situation in this furnace did not appear to be discussed between the engineering/inspection personnel responding to the reports of hot spots and the engineering staff considering the raise in temperature threshold. As a result, this information was not considered as part of the discussion with the manufacturers representatives, nor the decision to change the tube skin temperature alarm set point from 970 degrees F to 990 degrees F. Had it been raised, this critical piece of information would have elicited entirely different advice.

Handling Hot Spots

Refinery training and operating manuals highlight the significance of hot spots and the importance of handling them quickly. These manuals identify the action that operators should follow when hot spots are detected. The operators followed procedure by reporting hot spots to the head operator and by attempting to control the flame and tube skin temperature by adjusting burners.

The verbal testimony of refinery personnel was that hot spots are serious and would result in shut down. There is no documentation that identifies the direction to shut down when hot spots are detected. Although the operator manual specifies the action operators should take when hot spots are detected, there are no further procedures specified for other staff, including the head operator.

The Refinery Equipment Manual description of temperature-induced tube skin colour changes seems to conflict with metallurgical documentation identifying the temperature-induced tube skin colour changes characteristics of 347H stainless steel.

Refinery engineering and inspection personnel erroneously attributed hot spots to burning scale on the tubes and determined that burner adjustments were an adequate remedy. They distinguished a difference between hot spots from glowing scale as opposed to overheated base metal. However, they did not seem to differentiate between the metallurgical characteristics of 347H stainless steel in these tube banks and the characteristics of ferrous tube banks in other furnaces. Scale on Type 347 stainless steel tubes only forms at temperatures in the order of 1300 - 1500 degrees F, well above the design specification limits. Recognising this should have been an indication of a serious condition.

There did not appear to be any reference in the manuals to the different metallurgical properties of tube material and the characteristics displayed. There was no information indicating a definitive method to make the distinction for the cause of hot spots, or a rationale for having to make the distinction. Refinery inspection staff were interviewed and were confident of their conclusion. There is no information on the adequacy of training for the engineering or inspection staff. The employees involved in the decision making were professional engineers and employees with in excess of 20 years refinery experience. It could not be determined if the response from refinery engineering and inspection personnel was result of a lack of training or of bad judgement.

In determining whether reasonable measures were taken to handle hot spots, a comparison was made to see if actions taken were consistent with the manner in which other refineries would react. Of the four refineries contacted, two would have handled the situation in an identical manner, one indicated that it did not have hot spot problems, and one took a more conservative approach, in that it would shut down the unit and perform non-destructive testing. All agreed that the appropriate procedure for immediately controlling hot spots was to reduce the burn rate and ensure there is no flame impingement.

Determining the Impact on Tube Life

There was no indication in the documentation to advise that different tube materials demonstrate different metallurgical properties, e.g. formation of scale, or the temperatures at which tube skins would reflect colour changes. There was no documentation making the connection between visible change in tube colour and an inherently dangerous condition. In addition, there is no indication of a process to relate over-temperature conditions to reduction of tube life in quantifiable terms. This means that even when hot spots are correctly identified there is no mechanism to determine the imminence of disaster.

The hydrocracker furnace is not classified as a boiler or pressure vessel under the Boiler & Pressure Vessel Act. However, the fired heater pressure coils, or tube banks, within the furnace are classified as Category H fittings under that Act. The current legislation requires the heater pressure coils to be registered with the Department of Labour, Safety Code Services. This department has been unable to confirm if the requirement existed, or the material was registered when the furnace went operational in 1975.

If the operating parameters remained under the maximum allowable pressure and temperature ratings required for the heater coil, the company would not be required to notify Safety Code Services or re-register. If the registered design pressure is exceeded, or if there was any increase in temperature that would cause the stress values to decrease from those used in the original design, this would constitute a new design. Because these changes would affect the thickness or design pressure, the company would require a new registration.

Department of Labour, Safety Code Services indicates that they would only inspect these kind of furnaces on scheduled shutdowns. Their inspector would check for alignment of the fired coil, refractory, supports and any reports of non-destructive testing done. They indicate that primary responsibility for checking the condition of the tubes rests with the company.

Conclusions

A Breach of the Act ?

There are no regulations under the *Occupational Health & Safety Act (OHS Act)* specifically dealing with the operation of refineries. Therefore this situation falls under the *OHS Act* Section 9 - duties of employer, more specifically Section 9(1)(a) - *take every reasonable precaution to ensure the health and safety of his employees,* and Section 9(2)(a) - *ensure that at the place of employment the necessary systems of work, tools, equipment, machines, devices and materials are maintained in good condition and are of a minimum risk to health and safety when used as directed by the supplier or in accordance with the directions supplied by the supplier.*

In order to determine whether or not there was a breach of the *OHS Act* the Commission would have to demonstrate that the employer did not take every reasonable precaution and had: an inadequate burner servicing and maintenance program; an inadequate tube skin temperature monitoring system; and inadequate procedure for handling hot spots; and an inadequate method for determining the impact on tube life.

The Commission's internal Accident Review Committee, which consisted of the investigating officers, the Chief Compliance Officer, Legal & Legislative Advisor and Director, Regional Services reviewed the file in-depth over the period January to May 1999. This Committee concluded that there was no compelling evidence of wrong-doing. However, the Committee did forward the file for an independent review by the Crown Prosecutor for a possible prosecution under the *OHS Act.*

The Crown concluded that it did not recommend a prosecution, because a prosecution under either of the two provisions of the OHS Act would not likely result in a conviction. It was felt that the employer would be able to successfully advance a defence of due diligence, and successfully argue that the danger could not have reasonably been foreseen. There was an adequate training program in place for operators and proper instructions had been given to employees and adequate information in place to ensure employee safety.

Coroner's Inquest

The Commission's practice is to refer an accident investigation file to the Coroner's office for review, once it has been determined that a prosecution will not be pursued. Commission staff met with the Coroner to discuss the circumstances surrounding this event and the findings and recommendations of the investigation, because an accident of this nature could have implications on public safety. A decision is pending by the Coroner.

Recommendations

Prevention

There are a number of recommendations being made to the workplace that, if implemented would prevent a similar occurrence. These are:

1. **The implementation of a formal, regularly scheduled preventive maintenance program for burners and the clean-up refractory debris to prevent flame impingement.**
2. **The introduction of a mechanism to more accurately and thoroughly monitor and record tube skin temperature to prevent hot spots.**
3. **The implementation of a more thorough and complete procedure to deal with hot spots once detected and reported. This includes the recording of descriptions and locations of any suspected hot spot detected in a visual inspection.**
4. **The introduction of a more accurate method to determine the impact on tube life once a hot spot is detected.**
5. **The refinery personnel be trained to recognise and respond to the changes in metallurgical properties and characteristics demonstrated by different material in the furnaces that are subjected to high temperature and pressure. Documentation to be updated to reflect this information.**

WHSCC Refinery Accident Investigation - Summary of Events

Event	Date
♦ Explosion occurred in east cell of hydrocracker unit	Tue, 9 June 1998 9:32 am
♦ WHSCC advised of explosion	Tue, 9 June 1998 9:50 am
♦ Officer notified	Tue, 9 June 1998 10:10 am
♦ Officer arrived on site, commenced investigation	Tue, 9 June 1998 10:20 am
♦ Officer met with Chief of Police - offer of assistance w/statements/photographs	Tue, 9 June 1998
♦ Regional Manager arrived on site	Tue, 9 June 1998
♦ Officer took charge of site once fire put out	Tue, 9 June 1998
♦ Officers commenced gathering information/records/documentation - maintenance/training/operation logs	Tue, 9 June 1998
♦ Officers went to Police department to take video witness statements	Tue, 9 June 1998
♦ Officers consulted with Fire Marshal, city fire department and Dept of Labour	Wed, 10 June 1998
♦ Meeting held with refinery personnel wrt securing area, dismantling of structure, removing stack, securing parts, pieces for analysis	Thu, 11 June 1998
♦ WHSCC forensic engineering consultant arrived on scene	Fri, 12 June 1998
♦ Orders issued to produce various drawings and other documentation	Fri, 12 June 1998
♦ Review of log books	Sat, 13 June 1998
♦ Progress meeting with refinery staff + their consultants	Sat, 13 June 1998
♦ Demolition continues, ends of east and west cells opened	Sat, 13 June 1998
♦ Statements taken from unit operators and inspection staff	Sun, 14 June 1998
♦ Met with refinery manager re: condition of other units, suggested refinery shut down schedule be advanced	Wed, 17 June 1998
♦ Acting Coroner arrived on site, met with Commission staff	Wed, 17 June 1998
♦ City Police provided video tapes for transcription	Wed, 17 June 1998
♦ Director met with refinery manager and senior company lawyer wrt Commission responsibility for investigation, testing	Wed, 17 June 1998
♦ Meeting w/ refinery personnel & consultants on procedure for removing & securing tube bank from east cell. Arranged construction of secure compound, overnight police guard	Sun, 21 June 1998
♦ Tube bank from east cell lifted and stored in secure compound	Mon, 22 June 1998
♦ Agreement by all parties as to initial testing protocol on critical tube samples (agreement preferable because of one chance to test due to destructive nature of testing)	Fri, 26 June 1998
♦ Cutting completed, samples crated, secured, shipped to Edmonton via independent trucker	Fri, 26 June 1998
♦ Refinery shuts down, advanced from September	Mon, 6 July 1998
♦ Samples arrive at lab in Edmonton	Tue, 7 July 1998
♦ Commission staff & forensic engineer meet with Lab personnel in Edmonton, remain on-site for one week	Mon, 20 July 1998
♦ Commission staff, forensic engineer and lab staff meet with refinery personnel and consultants to layout ground rules	Tue, 21 July 1998
♦ Testing starts on west bank tubes	Tue, 21 July 1998
♦ Inspection and testing of burners and pipe supports at refinery	Mon, 27 July 1998
♦ Received written confirmation from refinery that other units have been inspected and are serviceable	Thu, 30 July 1998
♦ Commission staff, forensic engineer and refinery personnel meet with Lab personnel in Edmonton, remain on-site for one week	Mon, 10 August 1998
♦ Testing of west bank tube samples complete	Mon, 10 August 1998
♦ Testing of all non-critical tube samples completed	Fri, 14 August 1998

Event	Date
♦ Testing of critical tube pieces commences	Wed, 9 September 1998
♦ More samples cut, shipped to Edmonton	November 1998
♦ Testing of tube samples complete	December 1998
♦ Received report from A.D. Tupper	January 1999
♦ Received report from Front Line Safety Ltd.	January 1999
♦ Received report from CANSPEC	January 1999
♦ Received report from In*nova*corp	January 1999
♦ Investigating Officers review material with Director	28January 1999
♦ Convened internal Accident Review Committee	2 February 1999
♦ Commenced clarification process with A.D. Tupper, In*nova*corp, CANSPEC	9 February 1999
♦ Reviewed additional documentation at refinery	1 March 1999
♦ Completed clarification process with A.D. Tupper	25 March 1999
♦ Review of material with Dept. of Labour , Safety Code Services	8 April 1999
♦ Accident Review Committee concludes	15 April 1999
♦ Review of case with Crown Prosecutor	26 April 1999
♦ Safety Code Services provides information on Boiler & Pressure Vessel Act	13 May 1999
♦ Crown Prosecutor completes review provides decision on prosecution	26 May 1999
♦ Investigation complete, findings report prepared	4 June 1999
♦ File referred to the Coroner for review	8 June 1999
♦ Met with Mrs. Hackett to review results of the investigation	8 June 1999
♦ Met with representatives of the refinery, union and JHSC to review findings & recommendations	9 June 1999